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Determinants of Energy Security Risk: Do Financial Development and Environmental Trade Matter?

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This paper examines the determinants of energy security risk across countries grouped by income levels. The study employs the Fully Modified Ordinary Least Squares (FMOLS) model, along with cross-sectional dependence tests and second-generation unit root tests, to assess the impact of environmental trade and financial development on energy security. The Pedroni Cointegration test is also used to determine the long-term relationship among the variables. The findings reveal that High-Income Countries (HICs) exert a non-significant effect on environmental trade, largely due to their advanced regulatory frameworks. Conversely, Upper-Middle-Income Countries (UMICs) demonstrate a significant positive influence of trade on energy security, particularly when trade openness exceeds a certain threshold. Low-Income Countries (LICs), however, exhibit weaker institutional capacity and limited resources, hindering the effective implementation of environmental regulations. The analysis further indicates that Information and Communication Technology (ICT) is negatively associated with energy security in UMICs. Evidence also suggests that greater trade openness increases energy security risk, implying that fluctuations in trade policies may create instability in the energy system. Overall, the study finds that financial development and environmental trade contribute to enhanced energy security by reducing dependence on fossil fuels. Policy recommendations include strengthening environmental regulation, fostering innovation, and promoting digitalization in HICs; improving institutional quality, advancing digital transformation, and implementing effective financial development policies in UMICs; and prioritizing institutional capacity-building, aligning trade policy with environmental objectives, sustaining economic growth, and expanding partnerships to support energy security in LICs.

Keywords: Energy Security Risk, Fixed-Effects Models, Cross-Sectional Dependence Tests, Second-Generation Unit Root, HICs, UMICs, LMICs.

INTRODUCTION

Energy security remains a critical global concern because energy transitions are complex and highly unpredictable. The shift toward net-zero emissions introduces inconsistencies between energy supply and demand due to unclear investment signals, technological limitations, ineffective policies, and infrastructural bottlenecks that undermine national energy security (IEA, 2021). Multiple factors, including digitalization, environmental trade, and financial development, shape energy security. The expansion of environmental goods, coupled with economic growth, encourages green investments and technological progress as countries move away from fossil fuels and nuclear sources toward renewable energy (Wang & Ullah, 2024).

Rising energy demand—driven by population growth and economic expansion—intensifies the challenge of ensuring a reliable energy supply. Countries with liberalized energy markets that rely heavily on oil, gas, and coal face increasing pressure to diversify their energy portfolios by adopting cleaner energy sources. Such diversification is essential to mitigate the risks posed by climate change, regional instability, and price volatility (Sovacool, 2011). A robust, flexible, and diversified energy mix is therefore vital for a smooth transition to a low-carbon economy and for managing risks associated with energy security (Welsch & Biermann, 2017).

Strengthening international cooperation on clean energy technologies is essential to simultaneously achieve environmental protection and energy security. Greater interconnection in the fields of research and development (R&D) and financing can advance low-carbon options such as nuclear power, renewables, and carbon capture technologies, enabling countries to reduce their high

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dependence on energy imports and diversify their supply mix (Jewell et al., 2019). Additionally, carbon pricing mechanisms—such as emissions permits and carbon taxes—encourage the adoption of low-carbon electricity sources and help reduce reliance on imported oil and gas, thereby improving energy security (Rabe, 2018).

The growing share of renewable energy in total power generation adds further complexity. Integrating utility-scale solar and wind power requires sophisticated planning to minimize the cost of variability. Emerging applications such as energy storage and demand-response systems offer potential solutions but may also introduce new security risks (Novikau, 2023). Moreover, the digital transformation of energy systems—including the use of 5G networks and blockchain technologies—enhances operational flexibility but simultaneously increases exposure to cyber threats. Strong coordination between energy providers and telecommunications sectors is needed to address these vulnerabilities (Yaqoob et al., 2022).

Financial development also plays a key role in strengthening energy security. It promotes portfolio diversification and reduces the impact of market disruptions and volatile energy prices (Badeeb et al., 2017). In addition, environmental trade supports energy security by facilitating the adoption of renewable technologies and reducing reliance on fossil fuels (Costantini & Mazzanti, 2012). However, political constraints and interest-driven agendas often hinder cooperation in advancing these shared objectives (Chantret et al., 2020).

Finally, the increasingly integrated nature of global energy markets means that cross-border disruptions and geopolitical conflicts can obscure underlying energy security vulnerabilities. Countries must confront the challenges arising from open markets, strategic competition, and dependence on imported energy supplies. Foreign direct investment (FDI) is essential for developing energy infrastructure, yet both FDI inflows and national energy policies may be affected by political instability and geopolitical tensions (Jiang & Martek, 2021).

MATERIALS AND METHODS

This study employs the level of an energy security risk index as the dependent variable, calculated by the International Energy Agency's Energy Security Risk index, ranging from 0-100 based on availability, affordability, reliability, and sustainability measures (Ang et al, 2015). Though some scholars criticized the index for oversimplifying energy security (Cherp & Jewell, 2014), this index is quite popular and suitable for this analysis. This study uses three World Bank income groups to classify countries: High-Income Countries (HICs), Upper-Middle-Income Countries (UMICs), and Lower-Middle-Income Countries (LMICs). These acronyms are defined here and used consistently throughout the study.

The independent variables include environmental trade (net trade in goods and services), ICT (internet usage percentage), foreign direct investment (FDI as a percentage of GDP), and trade openness (imports and exports as a percentage of GDP). These variables are sourced from the World Development Indicators and are well-established in the literature for their impacts on energy security and environmental sustainability (Shahbaz et al., 2021; Nathaniel et al., 2021; Destek & Sinha, 2020). The panel data covers 34 high-income, 24 upper-middle-income, and 11 lower-middle-income countries from 1990 to 2023.

***Cross-sectional dependency (CD) test*:** The study will employ a panel data analysis approach to examine the relationships among the key variables. A fixed-effect model (Baltagi et al. 2012) is used as a support model for cross-sectional dependency (Sarafidis et al. 2021) to account for unobserved country-specific heterogeneity. Furthermore, in panel data analysis to get unbiased estimation findings, there is a need to address the problem of CD. CD exists in the panel data set due to the regional and economic interlinkages, unobserved common factors, heterogeneity, and externality. The CD test helps exclude the mean value during the estimation analysis. Pesaran (2004) introduced the CD test, which is empirically shown as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\boldsymbol{\rho}}\boldsymbol{ij}$$

Where:

T is the number of periods.

N is the number of cross-sectional units.

Pij is the sample estimate of the pairwise correlation of the residuals.

Unit root analysis

Each variable's order of collaboration is disclosed through the application of unit root analysis. First-generation conventional unit root tests are not applicable after the panel data set indicates the existence of CD, as they are unable to address the issue of CD in the panel dataset. The second-generation unit root test, CIPS, was identified by Pesaran (2007). It is appropriate to use this test to verify that each variable has been integrated correctly after the CD has been present. The CIPS statistical form is shown as follows:

$$\text{CIPS}=\frac{1}{N}\sum_{i=1}^{N} ti$$

Where

I, t is the t-statistic for the coefficient βi from the CADF regression.

***Pedroni Cointegration Test*:** The Pedroni cointegration test is a statistical test used to determine the presence of cointegration in a panel data set. Cointegration occurs when two or more-time series are individually non-stationary, but a linear combination of them is stationary. The test was developed by Peter Pedroni (1999) and is widely used in econometrics and finance research.

The Pedroni test involves estimating the following equation:

$$\Delta yit = \alpha i + \beta i\, yit - 1 + \gamma i\, \Delta xit + \varepsilon it$$

Where:

- y_{it} is the dependent variable for individual i at time t
- x_{it} is the independent variable for individual i at time t
- α_i is the intercept term for individual i
- β_i is the Cointegrating vector for individual i
- γ_i is the coefficient on the first difference of the independent variable
- ε_{it} is the error term

The test statistic is calculated as:

$$Z = (N * T)^{\{\frac{1}{2}\}} \times \left(\Sigma_{\{i=1\}}^{N} \Sigma_{\{t=1\}}^{T} \varepsilon_{\{it\}}^{2}\right)^{\{-\frac{1}{2}\}} \times \left(\Sigma_{\{i=1\}}^{N} \Sigma_{\{t=1\}}^{T} \varepsilon_{\{it\}} * y_{\{i,t-1\}}\right)$$

The null hypothesis of no cointegration is rejected if the test statistic is greater than the critical value. Additionally, to examine the long-term relationship between energy security risk and other independent variables, like environmental trade, ICT, FDI, and trade openness in panel data, this study employed the Pedroni cointegration test. Firstly, the unit root CIPS test was conducted to ensure that the variables are non-stationary. The Pedroni (1999) cointegration test was chosen due to its ability to handle structural breaks, which are present in panel data. Unlike traditional cointegration tests, such as the Engle-Granger or Johansen tests, the Pedroni test offers robustness against structural breaks and is more reliable for datasets exhibiting such characteristics.

***Fully Modified Ordinary Least Squares*:** Fully Modified Ordinary Least Squares (FMOLS) is an econometric method developed by Phillips and Hansen (1990) to estimate consistent long-run relationships in cointegrated systems, where variables are non-stationary but share a long-term equilibrium. OLS is inefficient in this case because it is a biased and inconsistent estimator in the presence of cointegrated variables, but FMOLS controls for autocorrelation and endogeneity, thus being well-suited for capturing long-run coefficients.

In this study, FMOLS is used to capture the long-run relationship between the energy security risk, which is the dependent variable, and the variables of interest, FDI, ICT, trade openness, and environmental trade. Energy security risk is a measure of the availability, accessibility, and acceptability of energy, where higher risks are suggestive of higher exposure to risks of supply disruption. FDI, investment in communication technology, trade openness, and environmental trade contribute to energy security in various ways, for instance, through investment in energy infrastructure, smart grid technologies within the trade integration, and clean energy technologies.

The FMOLS estimation equation can be specified as:

$$ESR_t = \alpha + \beta_1 FDI_t + \beta_2 \text{Etrade}_t + \beta_3 ICT_t + \beta_4 OPN_t + \varepsilon_t$$

We first analyze the variables for stationarity and confirm the order of integration using the CIPS test. After that, the Pedroni cointegration test is performed to determine if at least one of the elements in the model is in a long-run relationship with the variables. When there is cointegration, FMOLS is used to estimate the unbiased long-run parameters.

Nonetheless, the FMOLS technique is most appropriate when estimating endogeneity, serial correlation, and the long-run relationship between the energy security risk and the selected set of controls.

RESULTS AND DISCUSSION

***Descriptive Analysis*:** The Energy Security Risk (ESR) calculated from these figures for different income groups is: HICs 1073.319, UMICs 1167.46, whereas the LMICs are higher, with 1345.301 on average. The ESR varies significantly in each group, especially within LMICs. This implies that energy insecurity risk is higher and unpredictable within LMICs than in UMICs and HICs.

Trade values of the six environmental goods and services also vary with income level. The current cross-country average environmental trade value is highest in HICs, with an average value of 28.4 billion, which has a large standard deviation, while UMIC has an average of 11.3 billion. Out of the four groups, LMICs record the smallest environmental trade values, thus showing that high-income countries are more active in environmental trade. The degree of variation of environmental trade is evident in all the groups because the degree of involvement in environmental trades varies accordingly.

When it comes to ICT, HICs are the highest with the mean value of 49.06102, UMICs are second best with a mean of 28.82587, whereas LMICs recorded an average value of 20.56886. The relatively higher ICT values for HICs propose better accessibility and utilization of technology than other packs. In the same context, the trade openness is also highest for the UMICs, followed by the HICs, while the LMICs have the least revealing of being engaged in international trade.

From Table HICs received the largest FDI inflows, which were $4,143,614, followed by UMICs, which were $3,266,558, then LMICs, which were $1,932,065. The level of FDI fluctuation is relatively high for all groups, but the HICs receive the largest FDI flows. This pattern demonstrates how income level determines FDI attraction capability; a country has than middle income it will attract more FDI.

***Cross-Sectional Dependency Test*:** The results of the Pesaran CD, Friedman, and Frees CD tests all indicate significant cross-sectional dependence in panel data across High-Income Countries (HICs), Upper-Middle-Income Countries (UMICs), and Lower-Middle-Income Countries (LMICs). For all income groups, p-values are below 0.0000, leading to the rejection of the null hypothesis of no cross-sectional dependence. HICs exhibit the highest test statistics in all tests, suggesting a more pronounced issue of cross-sectional dependence compared to UMICs and LMICs. This is likely due to the stronger economic interactions and global

Table 1. Descriptive Analysis.

Panel	Mean	Min	Max	Std. dev	Data source
Energy Security Risk (ESR)					
HICs	1073.319	414.4785	2273.272	275.2792	IEA (1990-2023)
UMICs	1167.460	556.2156	5033.127	553.5576	
LMICs	1345.301	805.0208	3786.388	507.2171	
Environmental Trade(Etrade)					
HICs	2.84e+10	-2.52e+10	5.74e+11	5.64e+10	WDI (1990-2023)
UMICs	1.13e+10	-1.27e+10	1.45e+11	1.99e+10	
LMICs	1345.301	805.0208	3786.388	507.2171	
Information and communication technology (ICT)					
HICs	49.06102	0	102.0005	36.15955	WDI (1990-2023)
UMICs	28.82587	-15.69990	100.4043	30.55894	
LMICs	20.56886	.0001113	96.15023	25.92265	
Trade openness (OPN)					
HICs	6.22e+10	-6.77e+13	7.11e+13	3.25e+12	WDI (1990-2023)
UMICs	1.60e+11	-6.00e+13	5.32e+13	3.34e+12	
LMICs	1.11e+09	-3.78e+11	1.18e+11	3.51e+10	
Foreign Direct Investment (FDI)					
HICs	4.143614	-40.08635	106.5735	8.546770	WDI (1990-2023)
UMICs	3.266558	-5.683970	55.07288	4.550655	
LMICs	1.932065	-.2899932	11.93948	1.901459	

Table 2. CD test results.

CD tests	HICs		UMICs		LMICs	
	Test-stat	Prob	Test-stat	Prob	Test-stat	Prob
Pesaran CD	35.838	0.0000***	11.090	0.0000***	6.083	0.0000***
Friedman's test	296.44	0.0000***	122.81	0.0000***	81.18	0.0000***
frees CD	8.7970	0.0000***	9.4920	0.0000***	2.683	0.0000***

And *** show a significance level of 5%.

integration among high-income nations. The presence of cross-sectional dependence means that ignoring it could lead to biased test results and inconsistent estimations in econometric models (Pesaran, 2004; Frees, 1995).

The literature, including works by Pesaran (2004), Frees (1995), Baltagi (2008), and others, highlights the importance of accounting for cross-sectional dependence when analyzing macroeconomic or financial data across countries. Globalization and international economic linkages contribute to this interconnectedness, particularly among richer nations. Bai and Ng (2002) also argue that high-income countries, given their closer integration into the world economy, may exhibit different patterns of dependence than lower-income countries. Econometric methods that fail to control for cross-sectional dependence may produce inefficient estimates and biased inferences (Hill et al., 2018). Therefore, controlling for cross-sectional dependence is crucial for accurate and reliable economic analysis, especially in globally integrated economies.

***CIPS Panel Unit Root Test*:** The results from panel unit root tests, which examine the stationarity of variables across different income groups (High-Income Countries, UMICs, LMICs), reveal significant differences in stationarity between variables and income groups. In Case 1 (with only intercept at the level), variables such as Energy Security Risk (ESR) and Foreign Direct Investment (FDI) in UMICs and LMICs show negative test statistics (e.g., -3.067 for ESR in UMICs), suggesting that these variables may be stationary at their levels. However, caution is needed, as the test statistics are close to the critical values at the 1% significance level, indicating a slight possibility of non-stationarity. This implies that while these variables might be stationary, they are not definitive, particularly for UMICs and LMICs.

In Case 2 (with only an intercept at the first difference), the test results show stronger evidence of stationarity across all variables in the income groups. Variables such as ESR, environmental trade (E*TRADE), ICT, FDI, and trade openness exhibit significantly negative test statistics (e.g., -5.150 for ESR in HICs), indicating that they are likely integrated of order one (I(1)), meaning their first differences are stationary. This suggests that these variables tend to exhibit a unit root at their levels but become stationary after differencing. Such findings are crucial for time-series modeling, as stationarity is a key assumption in many

Table 3. CIPS Panel Unit Root Test.

Variables		Case 1: only intercept [at a level]			Case 2: only intercept [at first difference]		
		HICs	**UMICs**	**LMICs**	**HICs**	**UMICs**	**LMICs**
Energy Security Risk		-2.194	-3.060***	-3.353***	-5.150***	-5.294***	-5.315***
Environmental Trade		-1.641	-1.515	-0.750	-5.098***	-2.367***	-2.849***
Information and communication technology		-2.722	-2.697***	-1.351	-4.654***	-5.297***	-4.892***
Foreign Direct Investment		-4.144	-2.390***	-1.954	-6.266***	-4.877***	-5.098***
Trade Openness		-4.931***	-1.830	-1.880	-6.221***	-2.789***	-2.567***
Critical values	1%	-2.72	-2.78	-2.93	-2.72	-2.78	-2.93
	5%	-2.60	-2.65	-2.76	-2.60	-2.65	-2.76
	10%	-2.55	-2.58	-2.66	-2.55	-2.58	-2.66

*** Significant level: 1%

econometric techniques. These results, consistent with the literature, emphasize the importance of differencing panel data to account for non-stationarity and trends over time to ensure accurate analysis and forecasting (Baltagi, 2012; Hill et al., 2018).

***Pedroni Cointegration Test*:** All three test statistics from the Pedroni cointegration test yield strong evidence of variable harmony in lower-middle-income countries, thus rejecting no cointegration at conventional significance levels. The Modified Phillips-Perron t (p = 0.0046), Phillips-Perron t (p = 0.0220), and Augmented Dickey-Fuller t (p = 0.0075) all yield statistically significant p-values below the 5% threshold. Strong evidence base demonstrates that the variables maintain a stable long-run equilibrium relationship in LMICs, which is a prerequisite for producing valid econometric models. The strength of evidence comes from the Modified Phillips-Perron test that shows robustness against heteroscedasticity, together with structural breaks found in developing economy data.

The findings regarding upper-middle-income countries (UMICs) show both positive and negative results. Long-term associations exist between these variables since both the Modified Phillips-Perron t (p = 0.0108) and Augmented Dickey-Fuller t (p = 0.0073) values reject non-cointegration. The Phillips-Perron t (p = 0.1783) test could not reject the hypothesis of non-cointegration, possibly because its results are affected by autocorrelation and structural shifts in UMICs' developing economic circumstances. Since the results show this inconsistency researcher must exercise extra care and should use more reliable tests (Modified Phillips-Perron or ADF) to draw valid policy conclusions.

All three tests led to an uptown confirmation of cointegration in high-income countries, demonstrating p-values of 0.0000 resulting from Modified Phillips-Perron, Phillips-Perron, and Augmented Dickey-Fuller t-statistic tests. Exceptionally high test statistics like ADF t = 8.1503 indicate robust long-run equilibrium relationships happen in HICs because these countries have both robust institutional frameworks and developed markets. The variables in high-income countries exhibit enduring and interconnected relationships that make Vector Error Correction Models (VECMs) well-suited for their analysis. The consistent test results across the board add validity to the analysis performed with HICs' data.

Table 4. Pedroni Cointegration Test.

Lower Middle Income Countries		
	Statistics	**p-value**
Modified Phillips-Perron t	2.6060	0.0046
Phillips-Perron t	2.0147	0.0220
Augmented Dickey-Fuller t	2.4337	0.0075
Upper Middle Income Countries		
Modified Phillips-Perron t	2.2987	0.0108
Phillips-Perron t	0.9218	0.1783
Augmented Dickey-Fuller t	2.4416	0.0073
High Income Countries		
Modified Phillips-Perron t	4.9970	0.0000
Phillips-Perron t	5.4200	0.0000
Augmented Dickey-Fuller t	8.1503	0.0000

***Fully Modified Ordinary Least Squares (FMOLS)*:** The comparison of the effect of environmental trade on the dependent variable by income groups shows a mixed picture. As for the effect of environmental trade on the dependent variable within high-income countries (HIC), the coefficients estimating the parameters of this variable are -1.92E-10, t =-0.836641, p = 0.4033, which means that there is not much relationship between them. This might be due to some established institutions in global environmental trade, hence reducing the effect on the environment. On the other hand, when environmental trade is included as a right-hand side variable in the estimation, it is statistically significant and positive as it has coefficient estimate of 1.00E-08(t=4.451723, p=0.0000). This implies that as these nations developed, they are in the process of harmonizing environmental standards into trade policies for economic growth, to environmentalism. Analyzing the results for the lower-middle-income countries (LMICs), the finding shows a coefficient value [.015963] and t-stat [.1325693]; the environmental trade does not influence the dependent

Table 5. Fully modified ordinary least squares (FMOLS).

Variable	Coefficient	Std. Error	t-statistic	Prob.
High-Income Countries				
Environmental Trade	-1.92E-10	2.29E-10	-0.836640	0.4033
Foreign Direct Investment	0.829658	0.194341	0.907383	0.3644
Information and communication technology (ICT)	1.847865	0.225849	8.181878	0.0000
Trade Openness	-7.47E-13	2.12E-12	-0.352860	0.7243
Upper Middle Income Countries				
Environmental Trade	1.00E-08	2.25E-09	4.451723	0.0000
Foreign Direct Investment	-0.498759	5.714624	-0.872770	0.3831
Information and communication technology (ICT)	-5.087286	0.950259	-5.353570	0.0000
Trade Openness	1.49E-11	8.72E-12	1.705113	0.0886
Lower Middle Income Countries				
Environmental Trade	0.015963	0.012041	1.325690	0.1858
Foreign Direct Investment	-1.489794	0.009188	-162.139000	0.0000
Information and communication technology (ICT)	-0.090614	0.027972	-3.239490	0.0013
Trade Openness	-20.535720	0.027720	-740.816000	0.0000

variable. This may be due to relatively low institutional development and possibly other competing, more pressing economic needs.

As it relates to FDI, the paper concludes that there is no conformity between FDI and the level of energy security in HICs. Although the coefficient has a positive sign (0.829658), this indicates that more FDI could, in theory, improve energy security; however, the t-statistic (0.907383) and the p-value tell us that this is not statistically significant. This could be because, unlike the emerging economies, which have young energy infrastructure and dependency on one source of energy, the HICs have diversified energy sources and infrastructure requirements that do not entirely depend on the FDI for energy security (Apergis & Payne, 2010). On the other hand, the coefficient estimate of Information and Communication Technology (ICT) is negative, and the magnitude is much larger; the coefficient = -5.087286, and the t-statistic is -5.353577 for the dependent variable of UMICs. This implies that although ICT has a possibility of spurring growth, it is not a guarantee that it will do this due to underlying factors that include infrastructure quality and digital skills (Dahlman et al., 2016; Vu, 2011).

Last, but not least, the variable independent trade openness is found to be positive though not significant to the dependent variable, as supported by the coefficient of 1.492E+08 with .0886 as the p-value. This is in concordance with other theoretical works pointing to the fact that trade liberalization may increase economic growth through market size and technology transfer (Frankel and Romer 1999); however, the insignificance implies a more complicated reality where domestic institutions and polices could be the determining factors (Rodrik, 2001). Therefore, more research is required in the future to explicate the relationship between trade openness and the dependent variable, controlling for other variables.

***Conclusion and policy recommendation*:** Energy security risk was chosen as a dependent variable of interest. The hypothesis was constructed to estimate the impact of financial development and environmental trade on ES risk across high-income, middle-income, and low-income countries. This study aimed to use a fixed effect model, and we checked cross-sectional dependence by using Pesaran's CD test, Friedman test, and Frees CD test, all of which confirmed cross-sectional dependence across high-income countries (HICs), upper-middle-income countries (UMICs), and lower-middle-income countries (LMICs).

From the CIPS panel unit root tests, we observed that different variables and income groups have incompatible degrees of stationarity. In the long-run test for the cointegration relationships, the FMOLS estimation procedures were employed. As it is illustrated in Table 4.2, cross-country environmental trade was statistically non-significant for energy security risk in the HIC sample, perhaps due to the robust environmental legislation in the sample country. Contrary, the above environmental trade positively impacted energy security risk in UMICs and reflected a major leap whenever the trade element was above the set thresholds. This study also revealed a lack of correlation between FDI net inflows and energy security in HICs, thus requiring policy adjustments.

The conclusions pointed to the fact that HICs should concentrate on the stability and further evolution of the regulation, as well as UMICs and LMICs, experienced in improving the institutional capacity to integrate environmental factors into trade. Further, the research showed that there was a negative relationship between Information and Communication Technology (ICT) and energy security risk in UMICs because of challenges in harnessing ICT resulting from low literacy levels or poor infrastructure. Trade openness had a statistically significant but marginal

relationship with energy security risk, thus supporting the last hypothesis that trade policies impacted the latter construct, but not consistently.

The content of policy recommendations, through digital transformation, environmental trade, and financial development, attempts to solve the problem of power security for all income segments. For the HICs, the recommendation focused on sustaining and enhancing effective environmental legislations, policies, fostering and encouraging technological development, financial diversification, and the investment in selective Information and communication technology (ICT for energy efficiency and reliability.

The recommendations for the UMIC are to introduce environmental performance in trade policies for exports, strengthen institutions and regulatory structures, reduce barriers to effective ICT use through complementary investments in education and infrastructure, and enhance financial development policies to fund investment in energy infrastructure modernization and diversification.

LMICs should undertake an approach to enhancing institutional and regulatory capacity, ensuring both internal and external environmental trade policies and regulations' Compatibility, supporting sustained economic development for enhanced financing in energy infrastructure, and especially adopting multilateralism and international knowledge-sharing efforts for learning and replication of applicable best practices and lessons learned in the event of future shocks.

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SDGs addressed: SDG 7–Affordable and Clean Energy;SDG 13–Climate Action;SDG 9–Industry, Innovation, and Infrastructure.

Policy referred: Strengthening Environmental Regulation;. Promoting Renewable Energy and Clean Technologies; Enhancing Financial Development.

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